National Association of Forest Industries

Timber Manual
Datafile SS3

Timber Floors

Commercial and Industrial

Revised Edition
2005

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Cover Photo: Crows ash flooring compliments cool informality of seaside restaurant

Timber flooring adds warmth and character to this restaurant

National Association of Forest Industries

Australian Government
Forest and Wood Products Research and Development Corporation

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Introduction

Timber has provided an efficient solution for commercial and industrial flooring applications in Australia for more than two hundred years. Wool stores, warehouses, shearing sheds and printing works are but a few of the traditional applications for timber floors. Many of these original buildings are now being upgraded and renovated to accommodate the needs of modern offices and inner city accommodation with the timber floors being retained as an integral part of these structures.

In new, modern buildings, the benefits of traditional timber floor systems can be used to advantage:

- resilience — easier to walk on
- appearance — can be left uncovered
- low maintenance
- good sub-floor for carpet, tiles, etc
- readily available
- high strength to weight ratio
- non-corrosive — suitable for chemical storage, etc
- can provide diaphragm action
- good resistance to wear and tear
- can be sound and fire rated

Modern timber engineering design will provide practical and economical flooring systems for a wide range of applications including:

- warehouses
- workshops
- shops
- restaurants
- sports halls
- offices
- libraries

Timber floor systems can be engineer designed to satisfy a wide range of load conditions. This Datafile provides design guidance for a limited range of loading situations and detailed engineered design should be undertaken for other load situations.

In addition to traditional tongue and groove (T&G) strip flooring, a range of wood based panel board products is available for flooring applications including:

- plywood
- particleboard

Hard wearing durable crows ash timber floor

Resilient brush box tongue and grooved timber sports floor

Tasmanian oak tongue and groove strip flooring compliments this restaurant/ bar

Parquetry and other specialised timber based flooring systems such as resilient sports floors and access floor systems, add further to the wide range of options from which to choose.

Scope

This Datafile provides information relevant to typical commercial and industrial applications such as sports halls, offices, warehouses, industrial buildings, libraries etc., where floor loadings are typically in excess of 1.8 kN point load and 4 kPa uniformly distributed load (ie: those used in houses).

The floors are assumed to be protected from the weather. Where appropriate, added protection (sealers, water repellents, temporary covers etc.) from potential damage by trades may be provided.

Whilst this Datafile covers predominantly T & G strip flooring, where relevant, it also refers to other wood based flooring products including parquetry and sheet flooring. For weather exposed applications, reference should be made to the *Datafile SS4*, *Timber Decks - Commercial industrial and marine.*

For floor loadings up to 1.8 kN point load and 4 kPa uniformly distributed load, reference should be made to AS 1684, *Timber Framing Code* or publications by the Timber Industry Associations in each state.

Standards, Grades and Quality Assurance

Tables 1 and 2 provide the information relevant to Australian Standards, grading and quality assurance programmes available for both floor framing and flooring.

It should be noted that whilst recognised quality assurance programmes may not be operational for some flooring products, third party certification of grading and compliance with Australian Standards can be provided by State Forest Services or Timber Industry Associations in each State.

Profiles

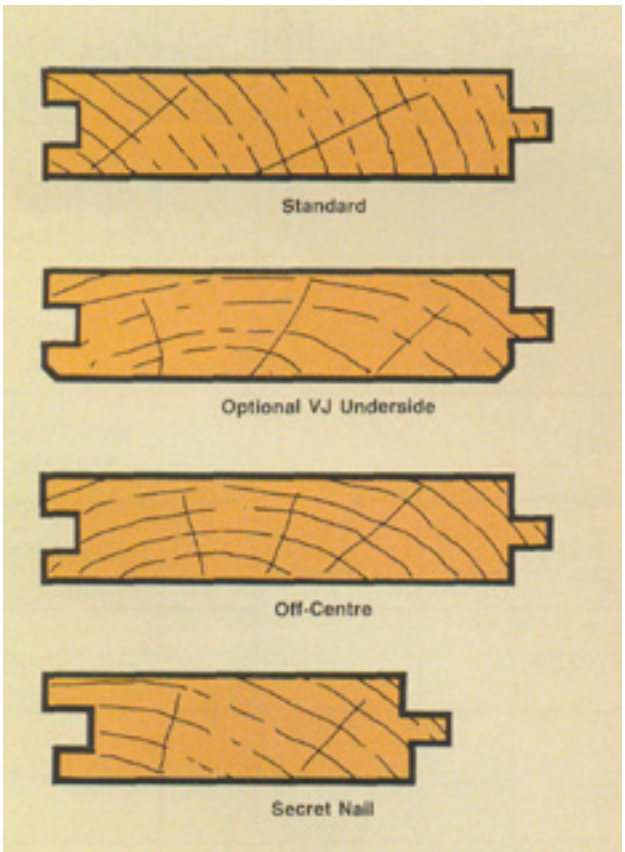
For T & G boards, some Australian Standards listed in Table 2 provide guidance on standard profiles and tolerances. Typically, 19mm T & G boards are machined with the tongues and grooves central about their thickness.

For special applications using 25 and 30mm thick boards, the tongues and grooves may be off-centre milled to provide for additional sanding during the life of the floor. Allowance should be made for sanding at the design stage. Off-centre milled flooring would be appropriate for applications such as squash court and gymnasium floors. Profiles for secret nailing are available, but should be restricted to boards having a nominal width of 80 mm or less for most hardwoods except for Tasmanian Oak which may be secretly fixed up to 85 mm in width.

As profiles and widths vary between individual suppliers, the availability of a particular profile should be ascertained from the supplier prior to its specification. Refer Figure 1 for typical profiles.

For greatest serviceability, board widths should be kept

Figure 1: Typical tag board profiles



to a maximum of 100mm. This will provide ideal fixing requirements and minimise movement due to seasonal moisture changes. It should also be noted that where high impact point loads are to be resisted, end-matched flooring should be avoided. Attention is drawn to the span reduction given by Note 3 in Tables 7 and 8, appropriate to end-matched floors. Tongues and grooves and end matching should be approximately equal to one third of the board thickness. For profiles of tongue and groove plywood and particleboard flooring refer to individual manufacturers.

Light coloured Victorian ash beautifies this foyer

Species Selection

Table 3 (page 6) provides a list of most commonly available species or species groups suitable for use in commercial and industrial flooring applications. The species name listed is the standard trade name as defined in AS/NZS 1148, Timber – Nomenclature – Australian, New Zealand and Imported Species. The strength groups and densities of the species are given to enable design and species selection based on suitability for purpose. It should be noted that hardness and wearability are often critical considerations in the selection of appropriate species for commercial/industrial applications. As a guide, where heavy wear or high wheel loads (pallet trucks etc.) are likely to be encountered, species with an air dry density in excess of 750 kg/m^3 should be used.

Table 1: Framing - standards, grades and quality assurance

Species	Australian Standard	Stress Grades
Hardwood - Unseasoned	AS 2082	F17 to F27
Hardwood - Unseasoned	AS 2082	F14 to F17
Softwood - Seasoned	AS 2858, AS/NZS 1784	F5, F8, F11, MGP10, MGP12, MGP15
Cypress - Unseasoned	AS2858	F4, F5, F7
Douglas fir - unseasoned	AS2825	F5, F7, F8

NOTE: Not all grades will be available Australia wide and suppliers or local industry associations should be consulted for specific local availability.

Table 2: Flooring - Standards, grades quality assurance

Type/Species	Thickness (mm)	Australian Standard	Grades
T & G Boards			
Hardwood	19, 25, 31 mm	AS 2796	Select, medium feature, standard, high feature
Softwood	19 mm	AS 1782	Standard (min)
	greater than 19 mm	AS 2858	Structural No. 2
Cypress	20, 31 mm	AS 1810	Grade 1
Plywood	12 to 39 mm	AS 2269	C-D F11- F34
Particleboard	19, 22, 25 mm	AS 1859	Class 1 Flooring
Mosaic Parquetry	Refer to Manufacturer	AS 2796	Select, medium feature, standard, high feature
Block Parquetry	Refer to Manufacturer	AS 2796	Select, medium feature, standard, high feature

NOTE: For standard thicknesses of plywood and particleboard flooring, refer to manufacturer

A colour description is also provided for species or species groups. This should be used as a guide only, as wide colour variation may occur within a single species. Species other than those listed may be available in local areas. Local suppliers should be consulted before finalising the species selection.

Moisture Content

Seasoned flooring is normally supplied with a moisture content between 9% and 14%. This moisture content range is usually satisfactory for ambient indoor conditions throughout much of coastal Australia. For some specific locations however, flooring should have a lesser moisture content (dry inland areas, continuously air-conditioned environment) or greater moisture content (tropical regions) depending upon the application.

Table 4 provides a brief summary of such conditions.

Where moisture contents greater or lesser than the 9% - 14% range are required, flooring suppliers should be advised of the desired range and average moisture content. However, it may not be feasible for manufacturers to provide flooring in an alternate range and therefore appropriate allowance will need to be made during installation.

Ideally, the flooring should be strip stacked in the building in its in-service environment (air conditioning turned on, if appropriate) for 4 to 6 weeks. This will allow the flooring time to stabilise prior to fixing. However, in many instances the in-service conditions can not be maintained for an appropriate period and alternative approaches need to be taken when installing the floor.

Design

Joists and Bearers

Span tables for uniformly distributed live loads from 2 to 4 kPa have been published in CSIRO, DBR special report: *Low Rise Domestic and Similar Framed Structures* — Part 5, Supplementary Design Information. Tables 5 and 6 extend these design tables to provide spans for 5 kPa uniformly distributed loads.

Where point loads (greater than 2.7 kN) are to be applied to the floor frame, the joist and bearer stresses should be checked using the provision of AS 1720, - *SAA Timber Structures Code.* For floor joist spacings exceeding 600mm, floor joist sizes shall be calculated in accordance with AS 1720, - SAA *Timber Structures Code*.

For design information on other timber products including laminated veneer lumber, glued laminated beams, parallel chord trusses and other sizes or stress grades of seasoned timber, refer to the manufacturers for details. For continuous spans greater than 4 m and/or for sections greater than 250 x 75mm, availability should be confirmed prior to specification.

Table 4: Moisture content ranges

Location/Application	M.C. Range	Average
Coastal Australia (except tropics)	10-15%	12%
Tropical and Wet Environments	13-17%	10%
Dry Inland	8-12%	10%
Air Conditioned Buildings	8-12%	10%

Double layered plywood sheet floor laid over concrete slab

Flooring

Allowable spans for point loads and uniformly distributed loads are provided for T & G flooring in Tables 7 and 8 respectively.

Similar design tables for plywood are published by the Plywood Association of Australia. For particleboard and glued-laminated flooring, individual manufacturers should be contacted.

Construction

On-Site Storage

Bearers and joists delivered to site should be block stacked on level bearers 150mm clear of the ground and protected by a water proof cover. Packs of timber should be kept strapped until required. Seasoned flooring delivered to site must be fully protected from the weather (i.e stored indoors under cover or equivalent) and kept clear of the ground.

Fixing

The minimum nail fixings recommended for T & G flooring are given in Table 9. All nails should be punched to 3mm below the top surface. To avoid splitting near the ends of boards or where boards butt together, nail holes should be pre-drilled to 80% of their diameter. For cypress joists, shear point (blunt) nails are recommended.

Mixed hardwood species have been used to enhance this gallery

Table 3 Some available flooring species/species groups

Species or Species Group	Strength group seasoned	Density 12% M.C. kg/m3	Colour
Mixed ash type eucalyptus eg. Tasmanian Oak Victorian Ash	SD4	660-800	pale straw to brown
Mixed open forest hardwood (excuding ash types)	SD3	770-1170	pale straw to dark brown
ash, alpine (1)	SD4	663	white to light brown
ash, mountain (1)	SD3	679	pale straw to pinkish brown
ash, silvertop	SD3	862	white to pale straw
blackbutt	SD2	884-930	pale to light brown
blackbutt, New England	SD3	880	pale to light brown
blackbutt, Western Australia	SD5	850	honey to light brown
box, brush	SD3	880	pink to red brown
box, grey	SD2	1110	white to light brown
cadaga	SD3	915	brown to chocolate
fir, douglas	SD5	540	pink to red brown
gum, blue southern	SD2	900	pake brown to pinkish brown
gum, blue Sydney	SD3	843	light red to red brown
gum, grey	SD2	1055	light red to red brown
gum, manna	SD4	778	pale pink to pinkish brown
gum, red forest	SD4	1010	light red to red brown
gum, red river	SD5	900	light red to red brown
gum, rose	SD4	750	light red to red brown
gum, spotted	SD2	1010	brown to dark brown
hardwood, Johnstone River	SD3	1000	brown to dark brown
ironbark, grey	SD1	1100	light brown to dark brown
ironbark, red	SD3	1090	light red to red brown

Table 3 (Continued)

Species or Species Group	Strength group seasoned	Density 12% M.C. kg/m3	Colour
jarrah	SD4	823	light red to red brown
kapur	SD4	750	pink to red brown
karri	SD2	910	light red to red brown
keruing	SD3	750	light red to light brown
kwila (merbau)	SD3	850	light red to light brown
mahogany, red	SD3	950	light red to light brown
mahogany, southern	SD3	920	red brown
mahogany, white	SD3	950	pale straw to dark brown
messmate (1)	SD3	770	pale straw to light brown
messmate, Gympie	SD3	1010	pale straw to light brown
pine, Carribean	SD6	575	pale straw to yellow (knotty)
pine, cypress white	SD6	675	pale straw to dark brown (knotty)
pine, hoop	SD5	560	pale straw to light brown
pine, radiata	SD6	545	pale straw to yellow (knotty)
pine, slash	SD5	625	pale straw to yellow (knotty)
stringybark, brown	SD3	840	pale straw to dark brown
stringybark red	SD4	900	light red to red brown
stringybark white	SD3	836	pale straw to light brown
stringybark yellow	SD3	884	yellow brown
tallowwood	SD2	1010	pale straw to dark brown
turpentine	SD3	945	pink to red brown
northern box	SD2	920	mid brown
manna gum	SD4	750	pale straw
shining gum	SD4	945	pale straw

Note: Species marked (1) are usually available only in mixed parcels as Tasmanian Oak.

Table 5: Bearers – 5.0 kPa live load and 2.7kN point live load for deflection = Span/360

Bearer Spacing (mm)	Size DxB (mm)	Single Span (mm)					Continuous Span (mm)				
Unseasoned Timber											
Stress Grade		F5	F8	F11	F14	F17	F5	F8	F11	F14	F17
2400	200x75	1400	1800	2000	2100	2200	1400	1800	2100	2300	2500
	200x100	1600	2000	2200	2300	2500	1600	2000	2400	2600	2900
	250x75	1800	2200	2500	2700	2800	1800	2200	2700	2900	3200
	250x100	2000	2500	2800	2900	3100	2000	2500	3000	3200	3600
	300x75	2100	2700	3100	3200	3300	2100	2700	3200	3400	3800
	300x100	2400	3100	3300	3500	3600	2400	3100	3600	3900	4200
	300x175	3200	3700	3900	4000	4200	3200	4000	4500	4600	4800
	350x175	3700	4200	4300	4500	4700	3700	4600	5100	5200	5400
	400x175	4200	4600	4800	5000	5200	4200	5200	5600	5800	6000
3600	200x75	1100	1400	1700	1800	1900	1100	1400	1700	1800	2100
	200x100	1300	1600	1900	2000	2100	1300	1600	1900	2100	2300
	250x75	1400	1800	2200	2300	2400	1400	1800	2200	2300	2600
	250x100	1600	2100	2400	2600	2700	1600	2100	2400	2600	2900
	300x75	1700	2200	2600	2800	2900	1700	2200	2600	2800	3100
	300x100	2000	2500	2900	3100	3200	2000	2500	2900	3200	3500
	300x175	2600	3300	3500	3600	3700	2600	3300	3900	4200	4400
	350x175	3000	3800	3900	4100	4200	3000	3800	4500	4700	4900
	400x175	3400	4200	4300	4500	4700	3400	4300	5100	5200	5400
4800	200x75	1000	1200	1500	1600	1800	1000	1200	1500	1600	1800
	200x100	1100	1400	1700	1800	1900	1100	1400	1700	1800	2000
	250x75	1200	1600	1900	2000	2200	1200	1600	1900	2000	2200
	250x100	1400	1800	2100	2300	2400	1400	1800	2100	2300	2500
	300x75	1500	1900	2200	2400	2700	1500	1900	2200	2400	2700
	300x100	1700	2100	2500	2700	3000	1700	2100	2500	2700	3000
	300x175	2300	2900	3200	3400	3500	2300	2900	3200	4200	4000
	350x175	2600	3300	3600	3800	3900	2600	3300	3900	4200	4600
	400x175	3000	3700	4000	4200	4300	3000	3700	4400	4700	5100
Seasoned Timber											
Stress Grade		MGP 10	MGP 12	F14	F17	F27	MGP 10	MGP 12	F14	F17	F27
2400	2/190x35	1400	1900	2000	2100	2300	1400	1900	2200	2500	2900
	2/190x45	1800	2200	2200	2300	2500	1800	2200	2500	2800	3100
	2/240x35	1800	2300	2600	2700	3000	1800	2300	2800	3200	3500
	2/240x45	2200	2600	2800	2900	3200	2200	2600	3200	3500	3700
	2/290x35	2000	2700	3100	3200	3500	2000	2700	3400	3800	4100
	2/290x45	2500	3100	3300	3500	3700	2900	3100	3900	4000	4300
3600	2/190x35	1200	1500	1800	1800	2000	1200	1500	1800	2000	2300
	2/190x45	1400	1800	1900	2000	2200	1400	1800	2100	2300	2700
	2/240x35	1400	1900	2200	2300	2600	1400	1900	2300	2600	2900
	2/240x45	1800	2100	2400	2600	2800	1800	2100	2600	2900	3400
	2/290x35	1700	2200	2700	2800	3100	1700	2200	2800	3100	3500
	2/290x45	2100	2500	2900	3100	3400	2100	2500	3200	3600	3900
4800	2/190x35	1000	1300	1600	1700	1800	1000	1300	1600	1700	1900
	2/190x45	1200	1500	1700	1800	2000	1200	1500	1800	2000	2300
	2/240x35	1200	1600	2000	2100	2300	1200	1600	2000	2100	2400
	2/240x45	1500	1800	2200	2300	2500	1500	1800	2300	2500	2800
	2/290x35	1400	1900	2400	2600	2800	1400	1900	2400	2600	2800
	2/290x45	1800	2100	2700	2800	3100	1800	2100	2700	3100	3400

Table 6 Floor Joists – 5.0 kPa live load and 2.7kN point live load for deflection = Span/360

Joist Spacing (mm)	Size DxB (mm)	Single Span (m)					Continuous Span (m)				
Unseasoned Timber											
Stress Grade		F5	F8	F11	F14	F17	F5	F8	F11	F14	F17
300	125x50	1900	2100	2200	2300	2400	2200	2500	2700	2800	2900
	150x50	2200	2500	2600	2400	2900	2700	3100	3200	3300	3500
	175x50	2600	2900	3100	3200	3300	3200	3500	3600	3700	3900
	200x50	3000	3300	3400	3600	3700	3600	3900	4000	4100	4300
	225x50	3400	3600	3800	3900	4100	3900	4200	4400	4500	4700
	250x50	3600	3900	4100	4200	4400	4200	4600	4800	4900	5100
	250x75	4100	4400	4600	4700	4900	4700	5100	5300	5500	5700
	275x50	3900	4200	4400	4600	4700	4600	4900	5100	5300	5500
	275x75	4400	4700	4900	5100	5300	5100	5500	5700	5900	6100
	300x50	4200	4500	4700	4900	5100	4900	5300	5500	5700	5900
	300x75	4700	5100	5200	5400	5600	5400	5900	6100	6300	6600
450	125x50	1600	1800	1900	2000	2100	1800	2200	2300	2400	2600
	150x50	2000	2200	2300	2400	2500	2200	2700	2800	2900	3100
	175x50	2300	2600	2700	2800	3000	2600	3100	3300	3400	3500
	200x50	2600	2900	3100	3200	3300	3000	3500	3600	3700	3900
	225x50	3000	3300	3400	3500	3700	3300	3800	4000	4100	4300
	250x50	3300	3600	3700	3800	4000	3700	4100	4300	4400	4600
	250x75	3700	4000	4100	4300	4400	4300	4600	4800	4900	5100
	275x50	3500	3800	4000	4100	4300	4100	4500	4600	4800	5000
	275x75	4000	4300	4400	4600	4800	4600	5000	5100	5300	5500
	300x50	3800	4100	4200	4400	4600	4400	4800	4900	5100	5300
	300x75	4200	4600	4700	4900	5100	4900	5300	5500	5700	5900
600	125x50	1400	1600	1700	1800	2300	1500	1900	2100	2200	2300
	150x50	1800	2000	2100	2200	2800	1800	2400	2500	2700	2800
	175x50	2100	2300	2400	2500	3300	2200	2800	3000	3100	3300
	200x50	2400	2700	2800	2900	3600	2500	3200	3400	3500	3900
	225x50	2700	3000	3200	3300	4000	2800	3600	3700	3800	4000
	250x50	3000	3300	3400	3600	4300	3200	3900	4000	4100	4300
	250x75	3400	3700	3800	4000	4800	3900	4300	4400	4600	4800
	275x50	3300	3600	3700	3800	4600	3500	4100	4300	4400	4600
	275x75	3700	4000	4100	4300	5100	4300	4600	4800	5000	5100
	300x50	3500	3800	3900	4100	4900	3900	4400	4600	4800	4900
	300x75	3900	4200	4400	4500	5500	4600	4900	5100	5300	5500
Seasoned Timber											
Stress Grade		MGP 10	MGP 12	F14	F17	F27	MGP 10	MGP 12	F14	F17	F27
300	120x45	2100	2200	1900	2300	2500	2400	2700	2700	2800	3100
	140x45	2400	2600	2600	2700	3000	2800	3200	3200	3300	3500
	190x45	3300	3500	3400	3600	3800	3700	4000	4000	4100	4500
	240x45	3900	4200	4100	4300	4600	4500	4800	4800	5000	5300
	2/240x35	4400	4600	4600	4800	5100	5100	5400	5300	5500	5900
	290x45	4500	4800	4700	4900	5300	5300	5600	5500	5700	6100
	2/290x35	5000	5400	5300	5500	5900	5900	6200	6100	6400	6800
450	120x45	1800	2000	1900	2000	2200	1900	2400	2300	2500	2700
	140x45	2100	2300	2200	2400	2600	2300	2800	2700	2900	3200
	190x45	2900	3100	3100	3200	3500	3000	3700	3600	3700	4000
	240x45	3500	3700	3700	3800	4100	3700	4400	4300	4500	4800
	2/240x35	3900	4200	4100	4300	4600	4400	4900	4800	5000	5400
	290x45	4100	4300	4300	4400	4800	4300	5000	5000	5200	5500
	2/290x35	4600	4800	4800	5000	5300	5000	5600	5500	5800	6200
600	120x45	1600	1800	1700	1800	2000	1600	2000	2100	2200	2500
	140x45	1900	2100	2000	2100	2400	1900	2400	2500	2600	2900
	190x45	2600	2800	2800	2900	3200	2600	3100	3300	3500	3700
	240x45	3200	3500	3400	3600	3800	3200	3800	4000	4200	4500
	2/240x35	3700	3900	3800	4000	4300	3800	4500	4500	4600	5000
	290x45	3700	4000	4000	4100	4400	3700	4500	4600	4800	5100
	2/290x35	4200	4500	4400	4600	4900	4400	5200	5200	5400	5800

Table 7: T&G Flooring - Allowable spans for deflection under point load = SPAN/180

Strength Group	M of E (MPa)	Thickness (mm)	Maximum Allowable Span (mm) for:						
			Point Loads of (kN)						Stiffness of 0.17 mm/100 N
			2	3	4	5	10	15	
SD2	18500	19	670	450	340	270	130	90	640
		25	1390	930	690	560	280	190	870
		30	2230	1480	1110	890	450	300	1160
SD3	16000	19	600	400	300	240	120	80	610
		25	1240	820	620	490	250	160	830
		30	1980	1320	990	790	400	260	1110
SD4	14000	19	540	360	270	210	110	70	580
		25	1110	740	560	440	220	150	790
		30	1780	1190	890	710	360	240	1050
SD5	12500	19	490	330	250	200	100	70	550
		21	730	490	370	300	150	100	630
		35	2410	1610	1210	970	480	320	1230
		45	3800	3040	2280	1820	910	610	1640
SD6	10500	19	430	280	210	170	90	60	510
		35	2100	1400	1050	840	420	280	1140
		45	3600	2640	1980	1590	790	530	1530

Table 8: Allowable spans for deflection under uniform distributed load = SPAN/360

Strength Group	M of E (MPa)	Thickness (mm)	Maximum Allowable Span (mm) for:					
			Uniform Distribution Loads of (kN)					Stiffness of 0.17 mm/100 N
			2	3	4	5	10	
SD2	18500	19	1250	1090	990	920	730	640
		25	1690	1480	1340	1240	990	870
		30	2060	1800	1630	1520	1200	1160
SD3	16000	19	1190	1040	940	880	700	630
		25	1610	1410	1280	1190	940	830
		30	1960	1720	1550	1440	1150	1110
SD4	14000	19	1140	990	900	840	670	580
		25	1540	1340	1220	1130	900	790
		30	1870	1640	1490	1380	1100	1050
SD5	12500	19	1090	960	870	810	640	550
		21	1220	1070	970	900	710	630
		35	2130	1860	1690	1570	1240	1230
		45	2770	2420	2200	2040	1620	1640
SD6	10500	19	1030	9000	820	760	600	510
		35	2010	1750	1590	1480	1170	1140
		45	2610	2280	2080	1930	1530	1530

Heavy duty cypress floor designed to take vehicular traffic

25 mm brush box strip floor designed to take loads up to 5 kPa

Notes to Tables 7 and 8:

1. *For many industrial and commercial applications, human response to floor movement will dictate allowable spans. It has been found from tests of human reaction that a deflection limit of 0.17 mm/100 N applied point load provides floors of satisfactory stiffness. The spans appropriate to this limit are given in the Tables.*
2. *For both Tables, the spans have been calculated assuming continuous spans, a 2 mm allowance for sanding and all end-joints over joists.*
3. *Where end-matched flooring is used, spans should be reduced by 40%.*
4. *The spans given in the Tables are based on the following formula respectively:*

   Point Loads – Table 7

   $$\delta = \frac{PS}{104\,T^{2.4}E^{0.8}}$$

   Where:
   S= Span in (mm)
   T= Thickness (mm)
   E= Modulus of elasticity (mm)
   δ= deflection in (mm)

   UDLs – Table 8

   $$\delta = \frac{12\,WS^4}{185\,ET^3}$$

   Where:
   S= Span in (mm)
   T= Thickness (mm)
   E= Modulus of elasticity (mm)
   δ= deflection in (mm)
5. *The spans given are based on assumed short duration live loads.*
6. *For Table 7, the deflection limit of span/180 is considered appropriate for point loads generated by pallet trucks, fork lifts and impact loads.*
7. *For other T&G flooring thicknesses, load durations or deflection limits, the formula under Note 4 may be used to calculate alternative spans. Refer to AS 1720, — SAA Timber Structures Code for guidance on duration of load factors.*
8. *The spans given satisfy the strength criteria relevant to the corresponding loads.*

19 mm radiata pine flooring has been used in this reception area

Typical fixing procedure for tongue and groove flooring

For applications where vibration or dynamic loading is of concern, the use of polyurethane flooring adhesive and/or screws should be considered. For corrosive environments, nails and screws should be either stainless steel or hot dipped galvanised.

Power-driven nails should be polymer coated and of length and diameter as recommended by the nail manufacturer.

Cramping

With floors laid on joists T & G Boards should be cramped up in sections (runs) not greater than 900mm wide and with power nailing (gun-nailing), nails may need to be hand punched to ensure boards are firmly seated. The last two boards at every run should be hand nailed at every second or third joist.

Temporary Floor Sealers

The application of commercially available floor sealers immediately after laying may provide additional temporary protection from the activities of wet and other trades if not complete. Such sealers will not provide protection or possible damage from excessive wetting.

Sub-floor Ventilation

The minimum sub-floor ventilation requirements for floors near the ground irrespective of whether it is T & G flooring, particleboard or plywood is 7500mm^2 clear area per metre of external wall and a minimum height to the flooring of 400mm except within 2 m of external walls where the height may be reduced to 150 mm. This ventilation requirement exceeds that in the BCA which is more concerned with durability issues of floor framing timbers.

Expansion Joints

For normal atmospheric conditions, T & G timber floors of widths up to approximately 6 m do not usually require intermediate expansion joints. Moist locations may however necessitate extra allowance for expansion. The edges of all floors, (parallel to boards), should be provided with at at least a 10mm expansion gap between the floor boards and the wall structure. Refer to Figure 2.

For floors of width greater than 20 m or for floors where variations in equilibrium moisture content (E.M.C.) will result in board moisture contents increasing by more than 3% above average (see Table 4), intermediate expansion joints should be provided at approximately 6 m centres (see Figure 2 on page 11) or gaps of approximately 2 mm should be incorporated into the floor at intervals of approximately 800 mm. The use of narrow T & G boards (75mm or less) will provide floors more tolerant of minor moisture variations for critical areas such as squash courts, dance floors, show rooms, etc.

Floors Over Concrete Slabs

These floors include gymnasiums, squash courts, community halls, etc. For many applications, it may be far more economical and practical to design and detail a floor support system using stumps or piles supporting

timber bearers and joists, than to fit a timber floor over a concrete slab. Designers should consider this prior to the specification of a slab. Timber floors are however, often required to cover concrete slabs and this can be for a number of reasons including:

- health (asthma and less rigid floor)
- aesthetics
- function (ie: dancing, sports and dynamics)
- fire ratings

Where this construction system is to be employed, the following factors should be considered.

Moisture Content of Concrete Slab

Moisture in concrete can occur for a number of reasons including:

- green slab
- broken vapour barrier
- through slab edges
- flooding
- leakage of plumbing

In all cases, this moisture must be removed and/or the cause of its occurrence remedied prior to the timber floor being fitted. Timber floors should not be fitted until a dry concrete slab is achieved. To ascertain if the slab is sufficiently dry for a timber floor or parquetry system to be laid, moisture meter readings in the slab should be below 5.5%. Alternatively hygrometers can be used in a sealed case above the slab and with this method the relative humidity should be below 75%. A representative number of samples are required with either of these methods. To quickly determine whether a slab is too moist, a sheet of glass (450mm square) can be taped to the slab and left 24 hours. If any moisture forms on the glass or the slab develops a damp patch (darkening) under the glass, the slab's moisture content is too high for the timber floor to be laid.

If doubt exists about the moisture content of the slab (existing or future), the top of the slab should be sealed with a proprietary sealer designed for the purpose or 200 µm polyethylene sheeting lapped and taped at joins and edges.

Preparing the Concrete Slab Surface

The top surface of the slab should be brought to an even, smooth surface using proprietary topping compounds and/or grinding where necessary. A tolerance of 3mm

This superb parquetry floor demeonstrates a skilful use of timber in Australia's parliament house

Figure 2: Expansion joints

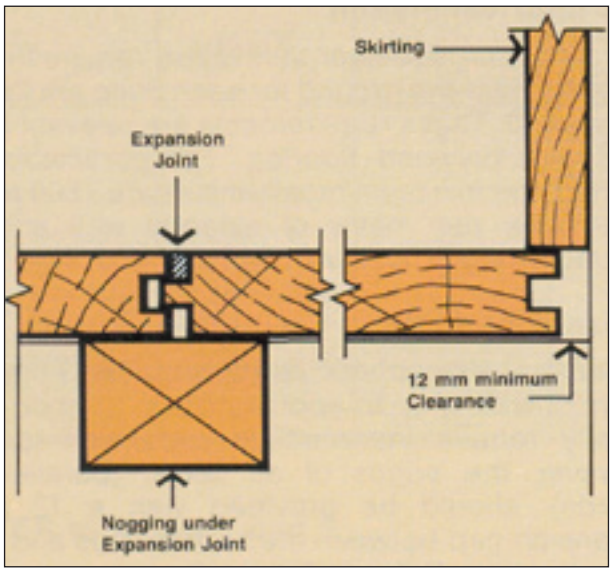


Table 9: Minimum nailing

Species	Thickness (mm)	Nailing Requirements
Hardwood and Cypress	19	50 x 2.8 Bullet Head
	25	60 x 2.8 Bullet Head
	30	65 x 2.8 Bullet Head
Softwood	19	50 x 2.8 Bullet Head
	35	75 x 3.18 Bullet Head
	45	90 x 3.15 Bullet Head

NOTES:

1. All nails to softwood joists should be deformed shank nails.

2. Use one nail per board crossing for widths to 75mm (nominal) and two nails for widths greater than 75 mm (nominal).

3. Stagger nails to avoid splitting joists

Typical fixing procedure for tongue and groove flooring

Particleboard offers an economical option for this commercial application

below a 3 m straight edge is considered a maximum for out of planeness.

Battens

For 19mm thick T & G flooring, 75 x 38mm or 50 x 50mm battens (sized) should be spaced in accordance with Table 7 or 8 (but not greater than 600mm). For T & G flooring 25mm or greater, 75 x 50mm battens should be spaced in accordance with Table 7 or 8 (but not greater than 1200mm).

Battens should be fixed to the slab at not more than 1200mm centres, (along the batten length), using countersunk M10 masonry anchors ("Dynabolts" or equivalent) 100mm long. Refer Figure 3 for typical details.

Boards should be fixed to battens in accordance with the general construction requirements detailed in Table 9.

Plywood and particleboard flooring should be fixed to battens in accordance with the manufacturers recommendations.

Under-Floor Ventilation

Under-floor ventilation should be provided to all elevated timber floors. This can be achieved by the installation of floor vents around the perimeter of floors or for large floor areas (greater than 100 m^2), forced ventilation may be necessary.

Sports Hall Floors

Resilient timber floors satisfy the needs of both the professional and amateur sports person. The dynamic response of these floors can be designed for specific needs (basketball, gymnasium, table tennis, squash, etc.), as either a suspended floor on timber bearers and joists (most economical solution) or as a timber floor over a concrete slab.

The following requirements should be considered:

- evenness of dynamic response (bounce, hard spots etc.)
- direction of boards (along the court)
- amount of sanding (initial and future)
- surface finish (required grip, slide, etc.)
- impact or point loads
- line marking
- colour
- maintenance

Suspended Floors

These floors are best detailed along similar lines to domestic construction. The support grid spacing should ideally be in the range 1.5 to 2.4 m with piers of either treated pine rounds (125mm dia.), steel RHS sections, masonry or concrete.

For average soil conditions, normal pad footings will suffice however, these should be designed to suit the specific site requirements and to comply with local authority by-laws. The stump spacings above will keep bearer and joist sizes within reasonable limits. This will also assist in providing floors with the required dynamic response. To obtain a floor with more even response, a "spring" can be incorporated into the bearer/stump connection. This "spring" can be achieved by isolating the bearer from the top of

the support by using a compressible neoprene pad of minimum size 100 x 75 x 12mm thick. The pad should have a Durometer rating of approximately 50-55. It should be noted that AS 1170, Pt. 2 - Loading Code - Dead and Live Loads specifies floor live loadings ranging from 2.0 to 5.0 kPa depending upon the application of the floor, with the 5.0 kPa being appropriate to crowd loadings, as may occur occasionally in multi-purpose halls. It has been found by experience that a 2.0 kPa UDL design load for bearers and joists will provide a sports floor in timber of about the right resilience for basketball and gymnastics.

For sports hall floors, a point live load of 3 kN is suggested as a minimum to account for general impact loads. Specialised cases (e.g., weightlifting) should be designed for their specific requirements.

Floors Over Concrete Slabs

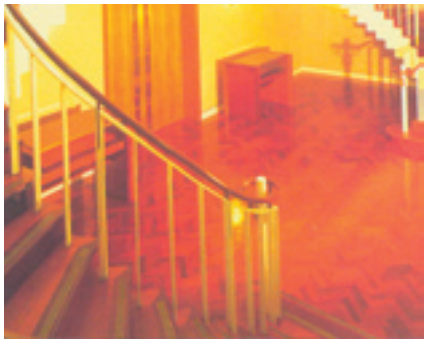
The general requirements for moisture content, smoothness etc., detailed on Page 17 should be followed. To obtain a resilient sports hall floor over a slab, a number of methods can be used including:

- double sprung Refer Figure 4.
- resilient pads Refer Figure 5.
- cushioned sheet flooring (proprietary systems).

The double sprung floor system requires about twice the depth (approx. 130mm) to install than the other systems and this should therefore be considered at the slab design stage.

The resilient pad floor system has been shown to provide a cost effective and efficient solution for T & G floors over slabs and is often used.

The specification on page 15 for a resilient pad floor



Jarrah parquetry in Senate entry to Australia's Parliament House

Sports floors are designed to withstand high impact loads

system has proven satisfactory throughout Australia.

Fire and Sound Ratings

Datafiles P5 - *Timber — Fire Resistance* and P6 - *Timber — Sound Control* provide details and design data on fire and sound rated floor/ceiling systems.

Design details Can be found in the NTDC publications on Multi-Residential Timber Framed Construction on www.timber.org.au/mrtfc

Finishing

Timber is an excellent flooring material, combining beauty, warmth and resilience with good wearing properties. However, to maintain these attributes over a long period, timber floors need a sealing treatment which needs to be distinguished from certain traditional surface treatments.

Many of the attractive properties of timber are due to its porosity, grain and fibrous structure. It is these pores which need to be sealed on the surface when the timber is brought into use.

Unsealed timber floors are liable to pick up dirt that may penetrate well below the surface and be impossible to remove even with vigorous cleaning. Spills of liquids are also apt to attack untreated timber discolouring it, either by introducing stains or by extracting some of the chemical constituents of the wood. The mechanical wear resistance, although naturally good, is improved by the use of a sealing treatment. When untreated timber wears, small bundles of wood fibres may become detached; this is disfiguring and also results in localised areas of excessive wear.

All these effects are more severe with open textured softwoods than with dense hardwoods, but are liable to occur in some degree with any timber. Consequently, any timber floor that is going to be left uncovered needs sealing, thus blocking the surface pores, to ensure that the floor stays:

- cleaner by keeping contaminating material out.
- hygienic by keeping bacteria out.
- unstained by keeping out discolouring liquids.
- less mechanically damaged by minimising differential wear.

Preparation of Floors

Before a seal is applied, timber floors should have nailheads punched below the surface and the holes stopped with filler. The floor is then sanded by machine, with successively finer grades of paper to yield a clean surface and a smooth finish.

If an old floor is being renovated, mechanical faults should first be repaired. In all cases, residues of any previous treatments, soda, detergents or deposits of dirt must be completely removed and the floor left free of dust. The only kind of surface treatment at all acceptable before sealing is a wood stain, but the type of stain must be compatible with the seal. Manufacturers' recommendations should be sought.

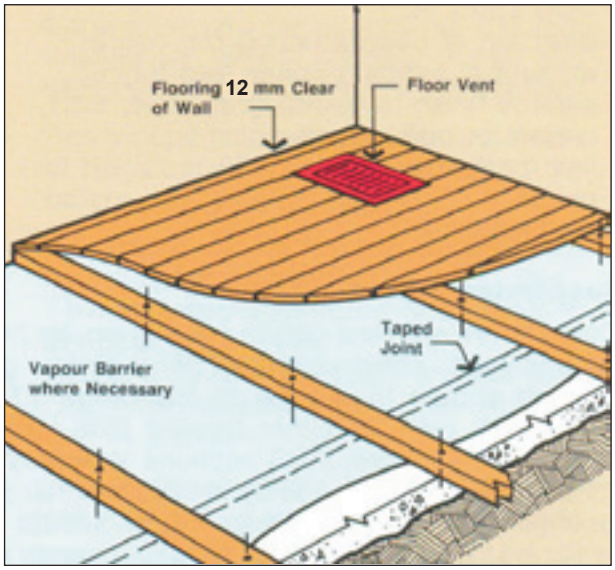
Timber Floor Finishes

Timber floor finishes can be grouped into the four broad categories. These are the oil-based finishes, composite finishes (mixes of oil-based and solvent borne polyurethane finishes), solvent borne polyurethane finishes and water borne finishes.

Oil-Based Finishes

Oil-based finishes (alkyd/oleoresins) are the more traditional types of finish manufactured by reacting a natural oil (e.g. linseed and tung) with another chemical. Varnishes and the traditional tung oils fall within this category and are associated with the polished and waxed timber floors of the past. These types of finishes are still available and require greater regular maintenance than the other finishes. However, with the use of acrylic floor polishes, they have become easier to maintain. These finishes will darken with time. They are flexible and are very unlikely to edge bond boards.

Figure 3: Typical details



Composite Oil-Based/Solvent Borne Finishes

Finishes containing oil-based alkyds with the addition of urethanes provide a finish with reasonably good abrasion resistance. Oil modified urethanes, which are one of the predominant floor finishes used in the USA and many of the 'tung oil' based finishes are of this type. The odour during application is very strong but dissipates as the finish dries. These finishes provide a subdued, satin to semi-gloss appearance and do not edge bond boards. They darken with time and require more frequent maintenance particularly in high traffic areas. Acrylic floor polishes may be used to protect the finish.

Solvent Borne Polyurethane Finishes

Solvent borne polyurethanes (one pack and two pack) provide a harder finish, generally with limited flexibility but much greater abrasion resistance. Consequently, this greatly reduces the level of routine maintenance. They currently provide some of the hardest finishes available today with gloss levels from matt through to a very high gloss. These finishes, as with the oil-based finishes, will generally darken with time and although hard, may scratch if care is not taken. Repairing such damage may require re-sanding and finishing. The odour during application is very strong with these products but

Figure 4: double sprung floor

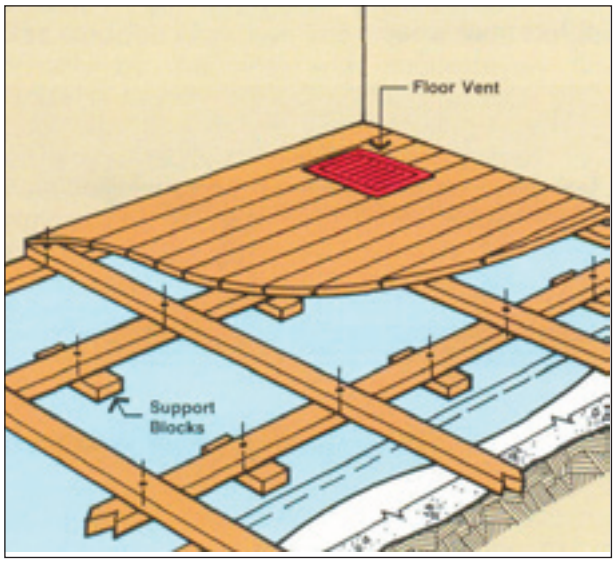
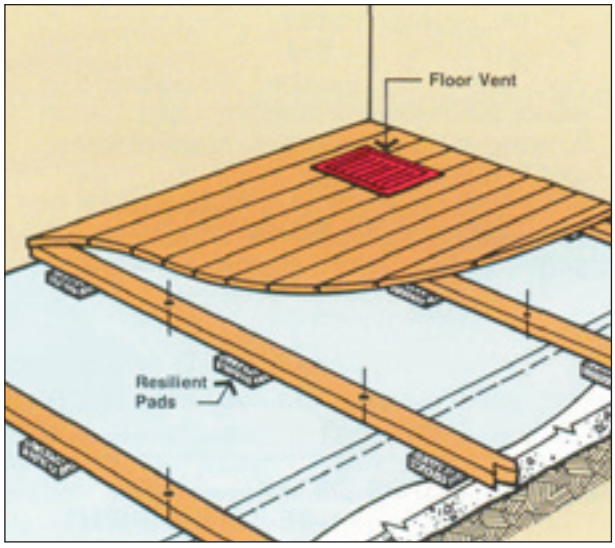


Figure 5: Resilient pad floor



Industrial application using particleboard sheet flooring over timber sub floor

Resilient Pad Floor System — Specification

(Refer Figure 5)

1. 200 µm polythene over slab lapped and taped at joins and 100 mm up the surrounding walls.
2. 50 x 50 x 12 mm neoprene rubber resilient pads with a 35-40 Durometer rating.
3. Seasoned Battens — 50 x 50 mm (nominal) sized to minimum of 45 x 45 mm. Species should be ironbark, spotted gum or equivalent, preferably seasoned.
4. Battens should be spaced at 400 mm centres for 19 mm flooring or 600 mm centres for 25 or 30 mm thick flooring.
5. Resilient pads to be stapled to underside of batten at 600 mm centres along the batten.
6. Battens should be fixed to the slab with countersunk masonry anchor (e.g., 7.9 mm thread tiger screw or equivalent) at 1800 mm centres.

   NOTE: The resilient pads are not to be compressed by the masonry anchors.
7. The ends of each batten should be supported by a separate resilient pad.
8. End-matched flooring should only be used on battens spaced at 400 mm centres, and should not be used where frequent impact loads are to be applied, (i.e., the goal zone of a basketball court). For those high impact areas, flooring should be butt joined over the battens.
9. Preferred species for 19 mm flooring are spotted gum, tallowwood and ironbark and for 25 and 30 mm flooring, any SD1-SD3 species listed in Table 3.
10. Flooring nails (including gun nails) should be punched 3 mm. below the surface. Nail holes to be stopped with a colour matching filler.
11. Floors should be fine sanded and then should be vacuumed clean of all dust and dirt prior to the application of one coat of a penetrating timber sealer in accordance with manufacturers directions. This is required prior to the commencement of line marking.

    NOTE: The line marking paint should be compatible with the floor sealer.
12. On completion of line marking, two coats of finish should be applied in accordance with the manufacturers recommendations.

dissipates as the finish dries. Due to their high strength and generally limited flexibility, edge bonding of boards can occur, unless an appropriate sealer is used.

Water Borne Finishes

Water borne polyurethane/acrylic mixes and straight water borne polyurethanes are gaining in popularity. They are generally applied over a sealer (either solvent or water based), that not only enhances the colour of the timber but also greatly reduces the risk of edge bonding. Rapid shrinkage in the floor can result in stretching of the finish at board joints with an appearance of light coloured lines at board joints. Matt through to gloss finishes are available and these finishes generally darken little with time.

During application there is low odour associated with water borne finishes. A curing additive (catalyst) may or may not be recommended by the manufacturer.

Table 11 outlines the types of finish available and lists various characteristics of each. When selecting a finish many aspects need to be considered including how the surface will wear, desired gloss level, frequency of maintenance coats and the expected seasonal movement in the floor after installation. Many sports floors use waterborne polyurethanes and have regular maintenance coats particularly in the goal zone.

Maintenance

For reasons of hygiene, floors will normally be regularly cleaned and this will have the further asset of helping to maintain them in good condition. Spills should be wiped up immediately

The method and frequency of cleaning will depend on the area of the floor, the application (i.e. sports floor, shopping centre, dance hall, showroom) and the volume of traffic using the floor.

Grit is an enemy of any timber floor and for this reason regularly cleaned door mats play an important role. Regular use of dry anti-static mops and vacuuming (with well maintained brush head) is recommended for smaller floors to remove dust and grit.

As a general rule water and wood do not mix and therefore the use of any water for cleaning must be minimised. On smaller floors a mop that is damp to touch may be used and on larger sports floors ‘scrubbers’ are often used.

It must be emphasised that a wet mop or ‘scrubber’ that is inefficient in removing moisture can cause floors to cup and expand as the result of moisture penetrating the joints between boards. Harsh detergents and abrasive cleaners are to be avoided and therefore proprietary timber flooring cleaning products should be used.

It is also necessary to ensure that the finish is sound with these methods of cleaning. Eventually the seal will become thinner in the most heavily trodden parts. At this stage — that is before the seal has completely worn away — the floor should again be sanded back so that it looks even, and then resealed.

Table 11 - Properties of Coating Systems

Timber Floor Finishes							
Oil based Alkyds		**Composite**		**Solvent borne**		**Water borne**	
Tung oil	Linseed oil based varnishes	Oil modified Urethanes (OMU)	Urethane oil/alkyd ‘Tung oil’	2 pack Poly-urethane	Single pack Polyurethane (moisture cured)	Polyurethane/ Acrylic	Polyurethane
Less wear resistant finish requiring more frequent maintenance Very unlikely to edge bond boards				High wear resistant finish May edge bond boards. Less likely to edge bond when applied over an appropriate sealer.		Moderate to high wear resistant finish Unlikely to edge bond boards when applied over a sealer	
6-24 hour drying by solvent evaporation Some tolerance to waxes Moderate to strong odour on application Avoid inhalation and contact				1-4 hour drying by chemical reaction Not tolerant to waxes Strong odour on application Avoid inhalation and contact		2-4 hour drying by evaporation and reaction Not tolerant to waxes Minimal odour on application	
Matt to gloss levels Darkens with age Relatively easy to repair				Matt to very high gloss levels Darkens with age Some not easy to repair		Matt to gloss levels Less darkening with age Relatively easy to repair	
Generally ready for use 2-5 days from completion*				Generally ready for use 2-3 days from completion*		Generally ready for use 2 days from completion*	

*Varies with weather conditions and product. Full curing may take a longer time.

Seasoned 45 mm x 70 mm bearers fixed at 450 mm centres over a cured concrete slab

Specification

For recommended specification clauses, reference should be made to Datafile SP1, *Timber Specifications*. The following is a check list of items which should be included in specifications covering commercial and industrial timber floors:

Framing

- species
- stress grade
- seasoned or unseasoned

Flooring

- product (T & G, Plywood, Particleboard, etc.
- profile, size or thickness
- acceptability of end-matching
- grade

Fixing

- cramping
- fastener specification (nail/screw/glue)
- fastener spacing
- edge clearances/expansion joints

Finishing

- nail punching and filling
- sanding
- finishing product
- number of coats

Other References

1. *Wood in Australia*, K.R. Bootle McGraw Hill.
2. AS/NZS 2311 Guide to the Painting of Buildings, Standards Australia
3. *Finishes for Exterior Timber*, TRADA (UK).
4. *Surface Coatings*, Volume 1 and 2, Oil and Colour Chemists Association of Australia.
5. *Finishing Wood Exteriors, Selection, Application and Maintenance*, U.S. Department of Agriculture Handbook No. 647.
6. MRTFC Design and Construction Manuals - NTDC
7. *Guide to the Painting of Exterior Timber*, Australian Paint Manufacturers Federation Inc.

For further information contact these timber organisations:

NATIONAL

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Australian Plantation Products and Paper Industry Council (A3P)
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